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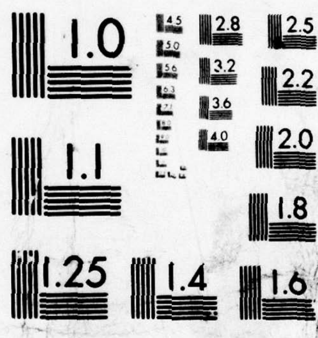

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TACTUAL DISCRIMINABILITY OF TWO KNOB SHAPES AS A FUNCTION OF THEIR SIZE

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JANUARY 1952

WRIGHT AIR DEVELOPMENT CENTER

NOTICES

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TACTUAL DISCRIMINABILITY OF TWO KNOB SHAPES AS A FUNCTION OF THEIR SIZE

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January 1952

Aero Medical Laboratory
Contract No. AF 33(038)-15474
RDO No. 694-17

Wright Air Development Center
Air Research and Development Command
United States Air Force
Wright-Patterson Air Force Base, Ohio

McGregor & Werner, Inc., Wakefield, Mass.
May 13, 1952 200

FOREWORD

This is a report describing an investigation conducted by the Psychology Branch, Aero Medical Laboratory, Research Division, Wright Air Development Center under Research and Development Order 694-17, Controls, Aircraft, Design and Arrangement, with Dr. W. C. Biel acting as Project Engineer. The study was done at the request of the Special Projects Branch, Aircraft Laboratory, Aeronautics Division. The experimental data were collected at Ohio State University, Columbus, Ohio under Contract No. AF 33(038)-15474 and under the direction of Dr. Delos D. Wickens.

ABSTRACT

In order to obtain data concerning the minimum size requirements for adequate tactual discriminability of the wheels and flaps airplane control knobs, five groups of 20 subjects each performed a task which required that they discriminate tactually between these two knob shapes. Subjects were allowed to view a knob shape presented in an aperture for about two seconds. Immediately following this they were required to grasp a lever containing one of the two knob shapes. The subject was to "operate" the lever if he thought that the knob shape sampled tactually was the same as the one viewed but was to remove his hand without moving the lever if he thought it was different. Errors of discrimination and total response time for each discrimination were recorded.

Five different knob sizes were used and each of the five groups performed the discriminative task with one of the different knob sizes. The major dimension of the knobs used varied in 1/4 inch steps from 1 inch through 2 inches. Each subject made 48 discriminations. Analyses were made of (1) average number of initially correct responses for each group, (2) average response time for initially correct responses for each group, and (3) average time required to make 48 correct responses for each group. None of these analyses revealed any statistically significant differences among the five knob size groups.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDING GENERAL:

Robert H Blount

ROBERT H. BLOUNT
Colonel, USAF (MC)
Chief, Aero Medical Laboratory
Research Division

TACTUAL DISCRIMINABILITY OF TWO KNOB SHAPES AS A FUNCTION OF THEIR SIZE

I. INTRODUCTION

In certain complex sensory-motor tasks an operator is required to make a variety of different responses to a variety of stimulating conditions. These responses may consist of manipulating such controls as knobs, levers and buttons. If space and speed of action are at a premium, it becomes necessary to bunch these controls in a limited area. When this is done, however, one cue which aids the operator in discriminating one control from another - the cue of spatial position - is minimized. This increases the opportunity for response errors since the operators are certainly more likely to operate the wrong control if it is separated from the correct one by only a few inches than if separated by a few feet.

One possible way of decreasing errors under such conditions is to supply the operator with other differential cues than positional ones. In many tasks the operator may not be able to look at the controls as he operates them or may not choose to do so, thus visually differentiating cues would not be utilized, but because he must touch the controls to operate them, he necessarily has an opportunity to use tactual cues to differentiate one control from the other. The basic assumption for the use of shape coding is that by supplying discriminable cues in addition to positional ones a reduction in response errors will be achieved.

One source of error in the operation of modern airplanes has been confusion between the wheels and flaps control levers, and accidents have resulted from this confusion.

In an effort to reduce such confusion, the Air Force is adopting the policy of shape coding these lever knobs so as to provide different tactual stimulation. The plan is to use a wheel-shaped knob for the wheels lever and a flap-shaped knob for the flaps lever. However, the problem has arisen as to the appropriate size of the control knobs. In the interest of conserving space they should be small, but they must be large enough to present clearly different tactual patterns even when an individual is wearing flying gloves.

The present study was conducted in an effort to supply an answer to the question of how tactual discrimination of these two knob shapes varies as a function of knob size when the operator is wearing a medium weight, flying glove, Type A-11A. The results should aid in answering the practical question of what knob size to use for these two controls.

II. APPARATUS

Although the particular problem under investigation is limited in scope and generality, the apparatus developed for its study has sufficient flexibility to be utilized in many other experiments.

Figure 1 gives a view of the apparatus from the subject's side. A starting plate is located at A. The subject's gloved left hand rests on this plate and depresses a microswitch before and after each trial. Knobs are exposed to

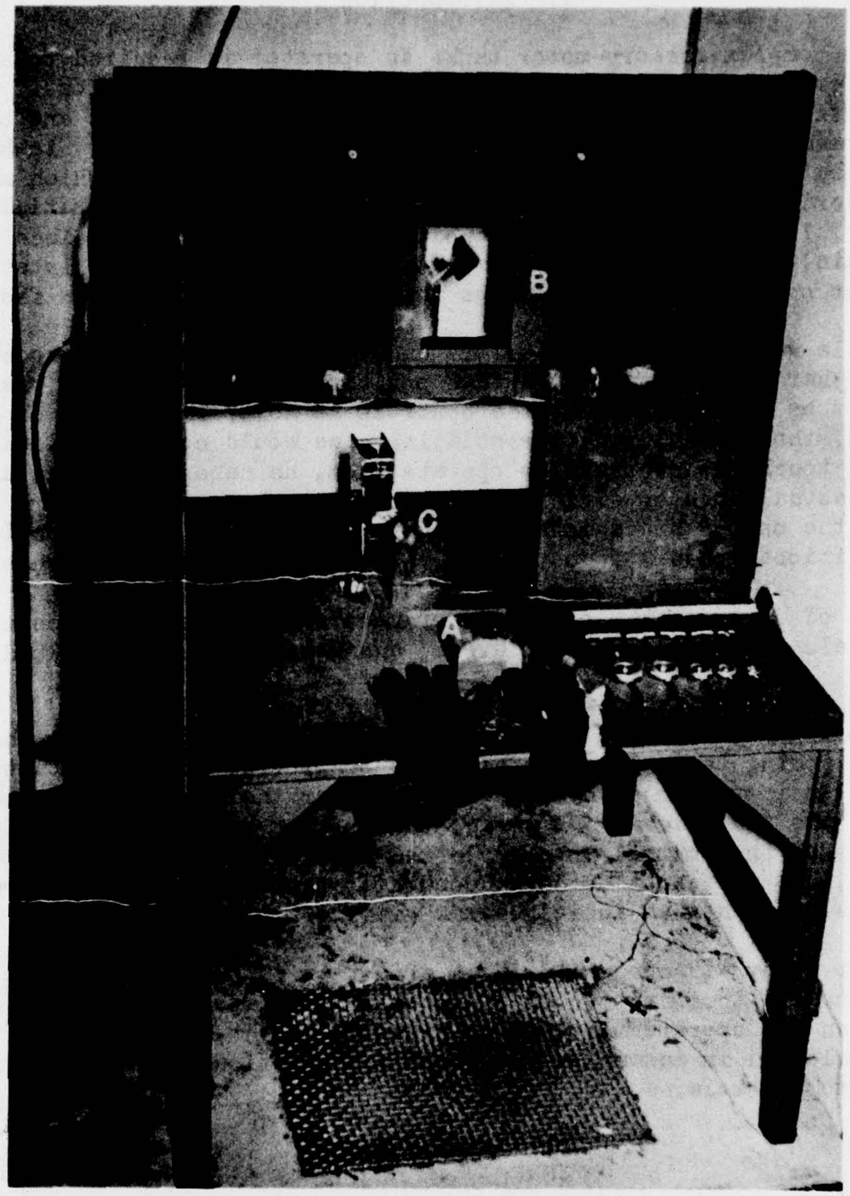

FIGURE 1: APPARATUS VIEWED FROM SUBJECTS' SIDE. KNOBS USED IN STUDY ARE SHOWN AT RIGHT.

the subject in window B, which can be opened or closed by the experimenter. The control lever is located at position C. This lever is in a horizontal position at the start of the trial and is depressed by the subject if he decides that the knob on the lever corresponds with the knob shown in the window. The particular knobs used either in the window or on the control lever can be readily changed by the experimenter from trial to trial and are locked into place by means of set screws.

Under operating conditions an opaque screen is placed between the subject's line of vision and the surface of the table, obscuring the starting plate and control lever from the subject's view. This is illustrated in Figure 2.

Five different Standard Electric time clocks measuring to 1/100 second are used to obtain the following time measures.

Clock 1 measures the time elapsing between departure of the hand from the starting plate and contact with the control knob.

Clock 2 measures the time elapsing between departure of the hand from the starting plate and <u>either</u> initiation of movement of the control <u>or</u> return of the hand to the starting plate, whichever is correct.

Clock 3 measures the total time the subject's hand is in contact with the control knob.

Thus the time taken to grasp the knob in response to the buzzer signal is measured by Clock 1. The time taken to judge and begin a correct response to a "same" comparison is measured by the difference between Clock 2 and Clock 1. The time taken to judge and begin a correct response to a "different" comparison is measured by Clock 3. The movement time for a correct response to a "same" comparison requires a fourth clock.

Clock 4 measures the total time the control lever remains in between the extreme positions of its range of movement. This time represents the movement time of a correct response to a "same" comparison.

Clock 5 measures the overall time for the trial. This clock starts simultaneously with the onset of a buzzer signaling the subject to reach for the control and stops when the hand has been returned to the starting plate after a correct response. The reaction time to the buzzer signal may be obtained by subtracting Clock 2 from Clock 5 for a response to a "different" comparison. The reaction time to the buzzer signal in the case of "same" comparisons cannot be obtained but there is no reason to believe that the nature of the comparison could have an effect on reaction time since the subject has no knowledge of the comparison until he grasps the knob.

The operation of those clocks which were started and-or stopped by contact of the gloved hand with the control knob was accomplished by means of a circuit containing a Thyratron tube which is activated by a weak current passing through

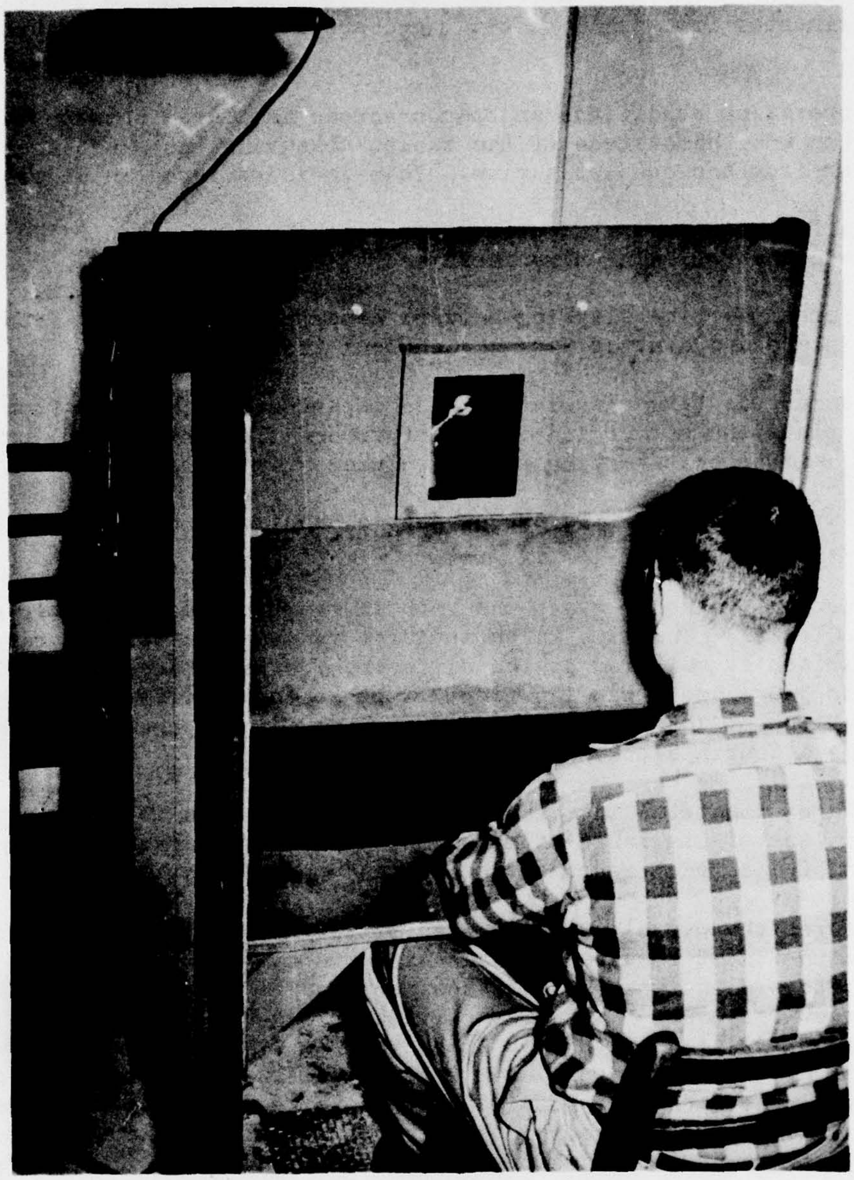

FIGURE 2: SUBJECT SEATED AT APPARATUS WITH OPAQUE SCREEN IN PLACE.

the subject's body. This current is not noticeable to the subject. The glove worn by the subject is coated with silver conducting ink to facilitate the operation of this circuit.

By using the time data from these clocks individually or in combination it is possible to obtain the time required for each component of the task. However, only the times from Clock 5 were analyzed in this experiment since it was felt that the total time measure was adequate to the purpose of this study. A complete description of the scoring clocks was given only in the interests of indicating the potentialities of the apparatus and the completeness of the data which are available if further analysis is desired.

The buzzer which signaled the subject to lift his hand from the starting plate and feel the control knob was purposely made rather intense and mildly unpleasant. It continued to sound until the subject completed a correct response. The purpose in designing and operating the signal in this manner was to aid in motivating the subject to respond rapidly.

Five different sizes of wheel and flap knobs were used. The diameters of the wheels varied by 1/4 inch steps from 1 inch through 2 inches. The flap knobs, which were square, also varied in width in 1/4 inch steps from 1 inch through 2 inches. The knobs employed are shown in Figure 1*. During the experiment the flaps were placed on the control so that their major dimension was horizontal; the wheels so that their major dimension was vertical.

III. SUBJECTS

The subjects were 100 students enrolled in the elementary psychology course at the Ohio State University. Half were males and half were females. The subjects were run in a continuous stratification procedure, the strata being sex and knob size. A total of 10 male and 10 female subjects was run on each of the five knob sizes making a total of five groups.

IV. PROCEDURE

1. Directions. When a subject reported to the experimental room, he was seated at the apparatus and told to keep his feet on a wire screen which grounded him. This grounding was required for the proper operation of the Thyratron circuit. The opaque screen was not in position at this time in order to allow the subject to see the position of the lever. Throughout the experiment each subject used his left hand in making the discriminations. This procedure was used in order to simulate as nearly as possible the actual situation in many of the latest types of aircraft. The following directions were read to him:

INSTRUCTIONS FOR WHEEL-FLAP DISCRIMINATION STUDY

(Seat subject, making sure his feet are on the wire screen. Explain that there is no shock.)

"In using flight controls in aircraft a pilot occasionally

*Engineering drawings of the two knob shapes along with the sizes of all major dimensions are presented in Appendix I.

grabs the wrong control and operates it, or he grabs the correct control but operates it in the wrong direction - incorrectly. There has been a recent development in the military services to code the knobs of certain controls with different shapes to enable the pilot to have a touch or shape cue as to whether or not he has grabbed the correct control when he reaches for a control without looking, or if the cockpit happens to be darkened. Knob shaped like wheels have been suggested for controlling the wheels; knobs shaped like flaps have been suggested for controlling the flaps. (Show the two knobs and identify). The experiment you are taking part in is designed to help the Air Force find out how accurately and quickly you can decide whether a control knob shape which you grab is the same as, or different than, a knob shape which you will be shown.

"Put this glove on your left hand. It is the same type of glove that pilots wear when they operate flight controls. Now place your left hand on the starting plate and hold the plate all the way down. The knob will be briefly shown to you in this aperture (show Knob A, the wheel, in aperture). Shortly thereafter a buzzer will sound (sound buzzer momentarily) and you are to reach as rapidly as possible with your left hand to this control knob and <u>grasp</u> the knob without looking at the control. After you have had some practice with the apparatus as it is now, this shield will be placed over the control area to simulate the pilot's "blind-reaching" situation. If the knob shape is the same as the one in the aperture, move the control downward as rapidly as possible until it hits the stop. Then return your hand to the starting plate as quickly as possible, pushing the plate all the way down. (Experimenter demonstrates). The buzzer which started earlier will continue to sound until your hand returns to the starting plate. That is, the buzzer will continue to sound until you have made the <u>correct</u> response. Now we will run through this sequence with the buzzer sounding. (Sequence is repeated by subject with buzzer operative).

"If you fail to move the control when you should, the buzzer will not stop when your hand returns to the starting plate, but will continue to sound until you have made the <u>correct</u> response. That is, you must grab the knob again and move the control down to the correct position. (The subject goes through this sequence with the buzzer operative).

"(Change knob on control to Knob B, the flap).

"If the knob shape on the control feels as though it were a different shape than the one in the aperture, do not move the control, but return your hand to the starting plate. Again, the buzzer will stop when this <u>correct</u> response has been made. (Subject goes through this sequence).

"If you should happen to move the control downward when it should not have been moved, the buzzer will continue to sound even though you return your hand to the starting plate. Move the control up to the correct position even if you have to grasp the control again, and then return yourhand to the starting plate. (Subject goes through this sequence).

"(Put shield on).

"Put your hand on the starting plate and try to move your hand from it to the control knob a few times so that you know where the knob is.

"Only two different shapes of knobs will be used - the wheel and the flap. Make your judgment in terms of shape only.

"I will now give some practice trials to get you acquainted with your task. Remember - move the control only when the knob shape is the same, but work as rapidly as you can. Operate these controls like you were in an airplane.

"Are there any questions?"

2. Practice series. The experiment was begun with a practice series of eight trials. In four of these trials the knob which was exposed visually and the knob on the control were the same (correct response - depressing the lever), in four trials the visual and tactual stimuli were different (correct response - removing hand from knob without depressing the lever). In half the trials the visual knob was a flap and in half it was a wheel. Thus, all possible combinations were employed equally often. The knob size used in this series was the same as that which the subject was to use later in the test series. Only one knob size was used for each subject in order to avoid interaction effects.

A trial was conducted in the following fashion. The aperture was opened exposing a knob visually for about two seconds. The buzzer was sounded after an interval from one to two seconds from the time that the aperture closed. This time interval was intentionally varied in order to prevent the subject from anticipating the buzzer. At the sound of the buzzer, the subject lifted his hand from the starting plate, contacted the lever, and made what he considered the correct response. If the response was correct, the buzzer was terminated immediately when his hand returned to the starting plate. If it was not correct, the buzzer did not terminate until the subject corrected his erroneous response and returned his hand to the starting plate. In other words, if the lever was not depressed when the knobs were the same, the subject had to return his hand to the knob and depress the lever before the buzzer was terminated. If he had depressed the lever when the knobs were different he had to return his hand to the knob and raise the lever back to the horizontal position before the buzzer would terminate when he returned his hand to the starting plate.

The experimenter recorded on his data sheet whether the initial response was or was not correct. The clock readings were also recorded on the data sheets.

3. Test series. The test series consisted of a total of 48 trials per subject. A two-minute rest period was given at the end of 24 trials. The procedure was the same as that described for the practice series above. Combinations of knobs were chosen in a random fashion so that 24 same and 24 different comparisons were made by each subject with no more than three same or different comparisons being made in succession. The experimental procedures were identical for each of the five groups.

V. RESULTS

Two kinds of data were recorded on each trial; whether or not the initial response made by the subject was correct and the total time required to make the response. Both kinds of data will be used in evaluating the discriminability of the five different knob sizes used in this study. In other words, a knob size will be considered good if a large number of the responses made are initially correct and if these correct discriminations are made rapidly.

Table I presents the average number of initially correct responses out of 48 trials for each of the five knob size groups. Knob size 1 was the smallest and knob size 5 the largest.

Table I

Average Number of Initially Correct Responses Out of 48 Trials for Each of the Knob Size Groups

Knob Size	Average Number of Correct Responses
1	45.15
2	45.55
3	46.50
4	46.25
5	45.85

From Table I it can be seen that the greatest number of initially correct responses was made with Knob Size 3; then in order came Knob Sizes 4, 5, 2 and 1. However, the differences among the groups are quite small. The Mann-Whitney "U" test was used to test for the statistical significance of the differences among the score-distributions of the various groups and none of the differences were found to be significant at the 5% level of confidence (1). Therefore, according to this criterion we cannot say that any one of the knob sizes is superior.

Table II presents the average response time in one hundredths of a second for initially correct responses for each of the knob size groups. It will be remembered that only the times from Clock 5 were analyzed in this study, i.e., the overall time

for a trial. A single time score was obtained for each subject by averaging these overall time scores for all initially correct responses made during the 48 trials. A single time score was obtained for each of the five knob size groups by averaging the individual subject time scores obtained in this manner.

Table II

Average Response Time in One Hundredths of a Second For Initially Correct Responses for Each of the Knob Size Groups

Knob Size	Average Response Time
1	143.29
2	146.05
3	148.79
4	139.02
5	136.25

Again the differences among the various groups is quite small and statistical comparisons made with the Mann-Whitney "U" test revealed that none of the differences among the score distributions were significant at the 5 percent level of confidence. Hence, none of the knob sizes can be considered superior according to a time criterion.

However, when the data from Tables I and II are considered together, the possibility of a further test is suggested. For example, in terms of number of initially correct responses, Knob Sizes 4 and 5, the two largest knobs, rank second and third respectively. In terms of response time they rank second and first respectively. The two smaller Knob Sizes, 1 and 2, on the other hand, rank fifth and fourth in terms of number of initially correct responses and fourth and fifth in terms of response time. Knob Size 3, which ranks first in terms of number of initially correct responses, is poorest with respect to response time. Thus the possibility suggests itself that differences between the knob size groups might show up if one could combine the two sets of data into one index. The two sets of data cannot be combined directly, of course, since the units of measurement are completely different. However, there is at least one way in which both the accuracy of response and response time can be reflected in a single index. It will be remembered that subjects were required to correct initially erroneous responses and that Clock 5 continued to run until such a correction was made. It is probable that the times for such responses would be considerably longer than for initially correct responses. A perusal of the data reveals that this is generally the case. Thus if one computes for each group the average time required to make the 48 responses correctly, the accuracy of responding will be reflected in this time measure. That is, the group which made the largest number of errors will have more "long" times added into this measure than a group which made fewer errors. This measure is presented for each of the groups in Table III.

Table III

Average Time in One Hundredths of a Second Required to Make 48 Correct Responses for Each of the Knob Size Groups

Knob Size	Average Time for 48 Correct Responses
1	7147.45
2	7264.00
3	7278.30
4	6845.85
5	6723.30

In terms of this composite measure, Knob Size 5 is ranked first, Knob Size 4 second followed in order by 1, 2 and 3. However, statistical analysis by means of the Mann-Whitney "U" test again reveals that none of the differences among the score distributions is significant at the 5 percent level of confidence. Thus, none of the measures used in this study reveals any statistically reliable differences in discriminability among the five knob shapes.

Some additional data of interest can be derived from the experiment. By comparing performance on the first 24 trials with performance on the last 24 trials, one can determine whether improvement occurred in this task. Subjects from all groups can be combined in this analysis since we are concerned with the overall learning effects. For example, of the 100 subjects in the experiment, 87 had a faster average response time for initially correct responses on the second 24 trials than on the first 24 trials, whereas only 13 had a slower response time. A Chi Square analysis reveals this to be significantly different at beyond the 1 percent level of confidence from the 50-50 split which would be postulated on the basis of a hypothesis of no improvement from first to second 24 trials. In general, more initially correct responses were made on the second 24 trials than on the first 24 trials also. It is somewhat more difficult, however, to get an index of the significance of this improvement since 41 of the subjects made 24 correct responses on the first 24 trials and hence couldn't be expected to show improvement. A rough index of the statistical significance of the improvement can be obtained, however, by considering only the 59 subjects who made errors on the first 24 trials. Of these 59 subjects, 41 made fewer errors in the second half than in the first half, 7 made more errors, and 11 subjects made the same number of errors in both halves of the experiment. If we divide these 11 cases equally between the other two groups, a Chi Square Analysis can be made. A Chi Square Analysis reveals this distribution of subjects to be significantly different at beyond the 1 percent level of confidence from the distribution that would be postulated on the basis of a hypothesis of no improvement from the first to the second half of the trials. Thus it appears that a significant learning effect did take place in this study in the sense that the subjects were performing the required discrimination better during the second 24 trials than during the first 24.

VI. DISCUSSION

Although in this study the mutual discriminability of the two knob shapes used did not vary as a function of knob size, it is not to be assumed that these results can be generalized to other situations. In this study at least one cue other than knob shape was available on which to base discrimination, namely, the orientation of the major dimension of the knob. The flap-shaped knobs were placed on the control so that their major dimension was horizontal and the wheel-shaped knobs so that their major dimension was vertical. This was done in order to duplicate the orientation of these control knobs in the newer-type Air Force planes, e.g., C-124. It is quite possible that different results would be obtained if the knob shapes were presented in the same orientation.

At least one other study, however, has obtained results similar to those reported here. Whittingham (2) compared the intra-series discriminability of four series of knobs of different sizes but containing the same or very similar knob shapes. Series 1 contained knobs whose largest diameter was 1.50 in., series 2, 1.25 in., series 3, 1.00 in., and series 4, .60 in. Each series of knobs was presented mounted on pegs placed vertically at the circumference of a round table top which could be rotated. Blindfolded subjects were allowed to feel a knob with their gloved, preferred hand and then, after the table top had been rotated, to sample knobs until they thought they had selected the knob originally felt. Each knob in a series was compared with its fellows in this way. Hesitations and mistaken identifications were recorded. On the basis of this information it was concluded that mutual discriminability was no greater for one series than for another.

One other point must be mentioned with regard to generalizing from the present study. It must not be assumed that the absolute values for response time and number of initially correct responses obtained in this study have any meaning when referred to the actual operational situation. They are useful only in making comparisons between the knob size groups. For example, even the best group with respect to the number of initially correct responses, Knob Size Group 3, made more than three percent errors. Such a percentage of errors could not, of course, be tolerated in practice. However, many differences exist between the discrimination situation provided in this situation and that provided in the operational situation. Naive subjects were used in this study whereas those making the discriminations in the operational situation are experienced pilots, positional cues are available in the aircraft whereas none were present in this study, and more time stress was present in this study than is usually present in the operation of an aircraft. This study was meant to provide data on the mutual discriminability of these two knob shapes as a function of size under certain conditions but was not meant to provide absolute time and error data which could be applied to the operational situation.

VII. CONCLUSIONS

1. It is concluded that the difference in the tactually discriminable cues provided by a vertically oriented, circular knob (the wheel-shaped knob) as compared with a horizontally oriented, square knob (the flap-shaped knob) was sufficiently great that size was a relatively unimportant variable within the range of knob sizes tested in this experiment.

2. It is further concluded, therefore, that in selecting a size to be used for both the wheel and flap controls, any knob size within the range used in this experiment may be used without materially affecting the discriminability of these two control knobs.

3. A significant improvement in performance between the first 24 trials and the last 24 trials was demonstrated.

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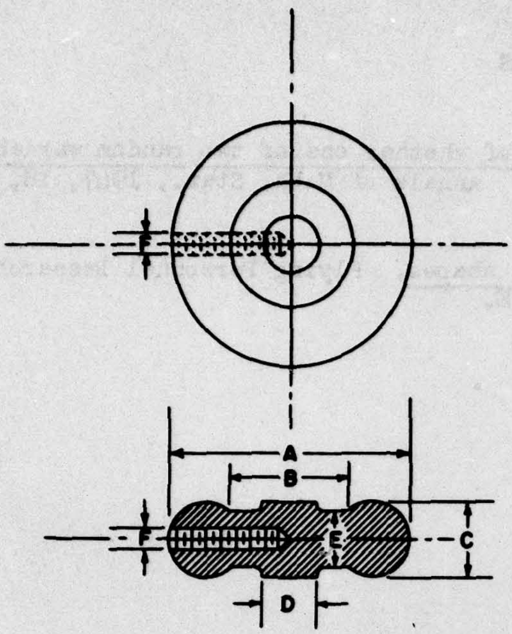
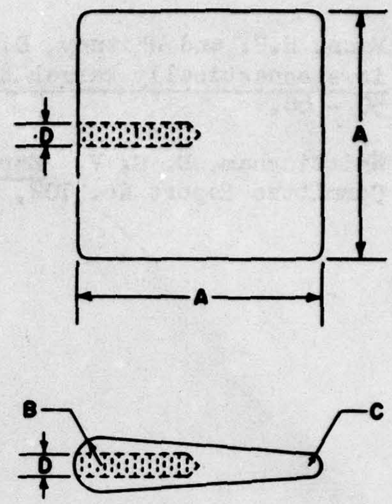
APPENDIX I





DIMENSION	KNOB 1	KNOB 2	KNOB 3	KNOB 4	KNOB 5
A	1.00"	1.25"	1.50"	1.75"	2.00"
B	.51	.64	.76	.89	1.02
C	.31	.39	.47	.55	.63
D	.25	.31	.38	.44	.50
E	.25	.32	.38	.45	.52
DRILL & TAP F	6-32	6-32	10-32	10-32	10-32

DIMENSION	KNOB 1	KNOB 2	KNOB 3	KNOB 4	KNOB 5
A	1.00"	1.25"	1.50"	1.75"	2.00"
B	.13	.16	.19	.22	.25
C	.05	.06	.07	.08	.09
DRILL & TAP D	6-32	6-32	10-32	10-32	10-32